MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020 SESSION

PTH0016 – MODERN PHYSICS AND THERMODYNAMICS

(All sections / Groups)

14 OCTOBER 2019
9.00 a.m. – 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 6 pages with 4 questions and an appendix.
2. Answer **ALL** questions.
3. Write your answers in the Answer Booklet provided.

Question 1 (15 marks)

(a) Transverse waves on a string have wave speed of 8.00 m/s, amplitude of 0.07 m, and wavelength of 0.32 m. The waves travel in the negative x-direction, and at $t = 0$ s, the particle at $x = 0$ m has maximum upward displacement.

(i) Determine the wave number and the angular frequency of the waves.

[2 marks]

(ii) Write the wave function describing these waves.

[2 marks]

(iii) Find the displacement of the particle at $x = 0.36$ m at time $t = 0.15$ s.

[1 mark]

(b) The human vocal tract is a pipe that extends about 17 cm from the lips to the vocal folds (also known as "vocal cords") near the middle of your throat. The vocal folds behave like the reed of a clarinet, and the vocal tract acts like a stopped pipe. Estimate the first three standing wave frequencies of the vocal tract. The speed of sound in air is 344 m/s. (Note: the answers are only an estimation, since the position of lips and tongue affects the motion of air in the vocal tract).

[3 marks]

(c) A stationary police car emits a sound of frequency 1300 Hz that bounces off a car on a highway and returns with a frequency of 1370 Hz. The police car is right next to the highway, so the moving car is driving directly toward or away from it. Take the speed of sound in air as 344 m/s.

(i) Determine if the car is moving toward or away from the police car.

[1 mark]

(ii) Calculate the speed of the car.

[6 marks]

Continued...

Question 2 (10 marks)

Light with wavelength $\lambda = 600$ nm is incident on a flat piece of glass with an incident angle of 25°. The index of refraction of glass is 1.52. Calculate:

(a) The angle of refraction when the light enters the glass

[2 marks]

(b) The speed of the light inside the glass.

[3 marks]

(c) The wavelength of the light inside the glass.

[3 marks]

(d) The angle of refraction with which the light emerges on the other side of the glass.

[2 marks]

Continued...

Question 3 (10 marks)

(a) Two different monochromatic light sources, one green (570 nm) and one violet (425 nm), are used in a photoelectric effect experiment. The metal surface has photoelectric threshold frequency of 6.2×10^{14} Hz.

(i) Calculate the frequency of light from each light source.

[2 marks]

(ii) Determine whether both sources are able to eject photoelectrons from the metal. Explain your answer.

[2 marks]

(iii) Calculate the amount of energy required to eject an electron from the metal surface in electron-volt (eV). [1 mark]

(b) An electron emits a photon of energy 1.3 eV when it makes a transition from the first excited state to the ground state in an atom.

(i) Calculate the ground-state energy (in eV) of the electrons.

[2 marks]

(ii) Calculate all energies (in eV) of photons that could be emitted when the electron starts in its second excited state and makes transitions downward to the ground state either directly or through intervening states. Then, show by sketching all these transitions on an energy level diagram.

[3 marks]

Continued...

Question 4 (15 marks)

(a) ${}^{124}_{55}Cs$ has a half-life of 30.8 s.

(i) If we have 8.8 μg initially, how many Cs nuclei are present?

[2 marks]

(ii) How many nuclei are present 2 minutes later?

[3 marks]

(iii) What is the activity at 2 minutes?

[2 marks]

(b) The heat capacity, C, of an object is defined as the amount of heat needed to raise its temperature by 1°C. Thus, to raise the temperature by ΔT requires heat Q given by $Q = C\,\Delta T$.

(i) Write the heat capacity in terms of the specific heat, c, of the material.

[1 mark]

(ii) What is the heat capacity of 1 kg of water?

[2 marks]

(iii) What is the heat capacity of 25 kg of water?

[2 marks]

(c) Name the following thermodynamic changes.

(i) A gas expands or compressed at constant temperature.

[1 mark]

(ii) A gas undergoes expansion or compression in which no heat enters or leaves the system.

[1 mark]

(iii) A gas undergoes a process in which the pressure is kept constant.

[1 mark]

Continued...

APPENDIX

LIST OF PHYSICAL CONSTANTS

Electron mass,	m_e	=	9.11×10^{-31} kg
Proton mass,	m_p	=	1.67×10^{-27} kg
Neutron mass,	m_n	=	1.67×10^{-27} kg
Magnitude of the electron charge,	e	=	1.60×10^{-19} C
Universal gravitational constant,	G	=	6.67×10^{-11} N m^2 / kg^2
Universal gas constant,	R	=	8.314 J/mol K
Hydrogen ground state,	E_0	=	13.6 eV
Boltzmann's constant,	k_B	=	1.38×10^{-23} J/K
Compton wavelength,	λ_c	=	2.426×10^{-12} m
Planck's constant,	h	=	6.63×10^{-34} J s
		=	4.14×10^{-15} eV s
Speed of light in vacuum,	c	=	3.00×10^8 m/s
Stefan-Boltzmann constant	σ	=	5.67 × 10-8 Wm^{-2}K^{-4}
Rydberg constant,	R_H	=	1.097×10^7 m^{-1}
Acceleration due to gravity of earth,	g	=	9.80 m/s^2
1unified atomic mass unit,	1 u	=	931.5 MeV/c^2
		=	1.66×10^{-27} kg
1 electron volt,	1 eV	=	1.60×10^{-19} J
Avogadro's number,	N_A	=	6.02×10^{23} mol^{-1}
Threshold of intensity of hearing,	I_0	=	1.0×10^{-12} W/m^2
Coulomb constant,	$k = \frac{1}{4\pi\varepsilon_0}$	=	9.0×10^9 N m^2/C^2
Permittivity of free space,	ε_0	=	8.85×10^{-12} C^2/N m^2
Permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ T m/A
1 atmosphere pressure,	1 atm	=	1.013×10^5 N/m^2
		=	1.013×10^5 Pa
Wien's displacement constant		=	2.90×10^{-3} mK
Speed of sound in air		=	343 m/s
Refractive index of air/vacuum	n	=	1.0
Earth: Mass,	M_E	=	5.97×10^{24} kg
Radius (mean),	R_E	=	6.38×10^3 km
Moon: Mass,	M_M	=	7.35×10^{22} kg
Radius (mean),	R_M	=	1.74×10^3 km
Sun: Mass,	M_S	=	1.99×10^{30} kg
Radius (mean),	R_S	=	6.96×10^5 km
Earth-Sun distance (mean),		=	149.6×10^6 km
Earth-Moon distance (mean),		=	384×10^3 km

Continued...

Formulae

$$\sin\theta_1 + \sin\theta_2 = 2\sin\left(\frac{\theta_1+\theta_2}{2}\right)\cos\left(\frac{\theta_1-\theta_2}{2}\right)$$

$$\cos\theta_1 + \cos\theta_2 = 2\cos\left(\frac{\theta_1+\theta_2}{2}\right)\cos\left(\frac{\theta_1-\theta_2}{2}\right)$$

$$\sin\left(\theta+\frac{\pi}{2}\right) = \cos\theta,\ \omega = k\upsilon = \frac{2\pi\upsilon}{\lambda},\ \omega = 2\pi f,\ Intensity = \frac{Power}{Area},\ \beta = 10\log\left(\frac{I}{I_0}\right)dB$$

$\sin\theta \approx \tan\theta \approx \theta$ *rad* for small angles

$$D(x,t) = D_M\sin(kx \pm \omega t \pm \phi)_1 n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2}$$

$$v = \sqrt{\frac{F_T}{\mu}},\ v = \sqrt{\frac{\text{elastic property of the medium}}{\text{inertia property of the medium}}},\ \mu = \frac{m}{L},\ v = (331+0.60T),\ v = f\lambda$$

$$f_n = \frac{nv}{2L} \qquad f_n = \frac{nv}{4L} \qquad \lambda_n = \frac{2}{n}L \qquad f' = f\left(\frac{v \pm v_o}{v \mp v_s}\right)$$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f},\ \frac{1}{f} = (n-1)\left\{\frac{1}{R_1} + \frac{1}{R_2}\right\},\ f = \frac{R}{2},\ n_2\sin\theta_2 = n_3\sin\theta_3,$$

$$\sin\theta_c = \frac{n_2}{n_1}\text{ with}(n_1 > n_2),\ {}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2},\ {}_1n_2 = \frac{1}{{}_2n_1} = \frac{v_1}{v_2},$$

$$d\sin\theta = m\lambda,\ d\sin(\theta) = \left(m+\frac{1}{2}\right)\lambda,\ a\sin(\theta) = n\lambda,$$

$$\lambda_m T = 0.2898 \times 10^{-2},\ I(\lambda,T) = \frac{2\pi c k_B T}{\lambda^4}$$

$$E_n = -\frac{mk^2e^4}{2\hbar^2}\left(\frac{1}{n^2}\right),\ r_n = \frac{\hbar^2}{mke^2}n^2,\ L = mvr_n = n\hbar$$

$$\frac{1}{\lambda} = R_H\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right],\ \frac{1}{\lambda} = \frac{mk^2Z^2e^4}{4\pi c\hbar^3}\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right],\ \lambda = \frac{h}{p}$$

$$R = R_0e^{-\lambda t},\ \lambda = \frac{\ln 2}{T_{1/2}},\ Q = mc^2 = (M_X - M_Y - M_\alpha)\ c^2$$

$$pV = nRT \qquad k = \frac{R}{N_A} \qquad N = N_0e^{-\lambda t}$$

$$\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{\Delta L} \qquad \frac{\Delta Q}{\Delta t} = e\sigma AT^4 \qquad \frac{\Delta Q}{\Delta t} = IeA\cos(\theta)$$

$$\overline{KE} = \frac{1}{2}m\bar{v}^2 = \frac{3}{2}kT,\ U = \frac{3}{2}nRT,\ Q = \Delta U + W$$

$$W = \int dW = \int_{V_i}^{V_f} PdV,\ W = P\Delta V,\ K_{max} = hf - w_o,\ V_{max} = \sqrt{\frac{2K_{max}}{m_e}}$$

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